Iranian Journal of Animal Biosystematics (IJAB)
Vol.18, No.2, 121-138, 2022
DOI: 10.22067/ijab.2022.79064.1041

IJAB

ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE **Open access**

Geospatial Analysis of Habitat Suitability for *Capricornis sumatraensis* (Bechstein, 1799) (Mammalia: Herbivora) in Annapurna Conservation Area of Nepalusing MaXent Model

Rajeev Joshi[1,*], Datta Bahadur Basnet[2] and Bishow Poudel[3]

[1]*Faculty of Forestry, Agriculture and Forestry University, Hetauda-44107, Makawanpur, Nepal; Amity Global Education (Lord Buddha College), CTEVT, Tokha -11, Kathmandu-44600, Nepal*
[2] *Tribhuvan University, Institute of Forestry, Pokhara Campus, Pokhara, Nepal*
[3]*Amity Global Education (Lord Buddha College), CTEVT, Tokha -11, Kathmandu-44600, Nepal*

(Received: *06 October 2022*; Accepted: *20 December 2022*)

Abstract

Himalayan Serow (Capricornis sumatraensis Bechstein) is the only sub-species of Serow that exists in Nepal. Capricornis sumatraensisis a threatened species that has been recorded and distributed across the protected mountainous areas of Nepal. A preliminary systematic survey was conducted to record the presence or absence. Secondary information included satellite imagery [Band 1-7 (30 m resolution) and Band 8 (15 M), topo-maps [features and settlement], Google Earth, and shapefiles. MAXENT and ArcGIS were used for data analysis for the habitat suitability mapping. Vegetation sample plots were established and Importance Value Index (IVI) was calculated from the field data for mapping vegetation preference. A focus group discussion, a questionnaire survey, and a key informant survey were done, and the Relative Threat Factor Severity Index (RTFSI) was used for ranking the threats for the threat assessment.

The calculated habitat suitability for C.sumatraensis determined that 18.3% of the total area was highly suitable, 16.8% was moderately suitable and the remaining 64.76% was less suitable habitat.A Quercus semecarpifolia and Rhododendron arboreum-dominatedforest was found to be the preferred habitat. In the preferred habitat, Drepanostachyum falcatum and Girardinia diversifolia were the dominant shrubs, and Anaphalis busua and Tracheophyta were dominant herbs. Poaching and hunting (0.927), open grazing (0.727), illegal resource collection (0.617), climate change (0.573) and development activities (0.447) were observed as major threats to theC.sumatraensis. The findings of the present research will be useful for conservation area managers, researchers, and academicians in the formulation of an appropriate conservation plan for this charismatic mammal species.

Key words: *Conservation, Distribution, Habitat preference, IVI, Threats*

INTRODUCTION

The Himalayan serow, *Capricornissumatraensis* (Bechstein, 1799), commonly found in Bhutan, Northern India and Nepal, known as "Capricornis thar", belongs to the tribe Rupicaprinae under subfamily Caprinae, family Bovidae and order Artiodactyla (Phan et al., 2020). The tribe is also commonly known as goat-antelopes (Mori et al., 2019). *Capricornis sumatraensis* is the only sub-species

Corresponding Author: joshi.rajeev20@gmail.com

of Serow that exists in Nepal (Bhattacharya et al., 2012). It has a large head, a thick neck, short limbs, long mule-like ears, and a coarse coat of dark hair. The *C.sumatraensis*looks like a cross between a cow, pig, donkey, and goat. *C.sumatraensis*is considered to be oriental in origin and confined to the forest slopes of the Himalayas (Aryal, 2008).

The *C.sumatraensis*enjoys densely wooded inaccessible river valleys and steep grassy hillsides with a nearby dense cover of oak and rhododendron (Mishra and Mierow, 1976). It prefers damp areas and is less tolerant of dry conditions, favoring an elevation of between 1500 m and 3000 m. Its feeding and habitat preferences also support solitary behavior. It also shows some sort of territorial behavior. *C.sumatraensis*is found to shift towards the lower altitudes in severe winter, but seasonal change in its home ranges in the Himalayas is not noticed. Currently, *C.sumatraensis* is foundBangladesh, Bhutan, China, India, and Nepal (Jnawali et al., 2011). In Nepal,*C.sumatraensis* is reported in Rara National Park (NP), Langtang NP, Sagarmatha NP, Shey-Phoksundo NP, Kanchanjunga NP, Makalu Barun NP, Annapurna Conservation Area (ACA), and Dhorpatan Hunting Reserve (Choudhary, 1998). The*C.sumatraensis*population in ACA is isolated in a small patch of the southern part of the area, with an estimated population density of 1.17 individuals/km and a population sex ratio of 1:1.6 (male: female) (Aryal, 2009). They have also been reported from Kanchanpur, Taplejung, Ramechhap, and Illam districts (Aryal, 2009).

Geographical information systems (GIS) are computer-based systems that are used to store and manipulate geographic information and are ultimately used to produce information needed by users (Aronoff, 1989). The focus of remote sensing in ecology and conservation science is on five broad capabilities: observation of habitat; analysis and management of biological and physical variables; mapping of the condition of a specific area at a specific time; monitoring how features have changed in the past over time and space; and decision support using trend information derived from remotely sensed products (Horning et al., 2010). A niche-based model represents an approximation of a species' ecological niche in the examined environmental dimensions. Species Distribution Models (SDMs), often referred to as Ecology Niche Models (ENM), allow the assessment of the suitability of a given area for one or multiple species and provide important information on ecological factors determining species distributions (Sillero, 2011). The output of SDM is increasingly used for multiple purposes, including the identification of conservation priorities, the prediction of species invasions, and analyses of the impact of environmental changes on biodiversity (Elith and Leathwick, 2009). There are a number of techniques that require presence-only data, such as environmental hype-space inhabited by a species method such as BIOCLIM, surface range envelope (SRE), distance-based methods by a species method such as DOMAIN, and discriminative techniques that require presence-absence data, such as General Linear Model (GLM), General Additive Models (GAM), Multivariate Adaptive Regression Splines (MARS), Classification, and Regression. Furthermore, SDM algorithms can be classified as follows: Regression methods such as GAM, GLM, and MARS; machine-learning methods such as ANN, BRT, MAXTENT, and RF; classification methods such as CTA and FDA; and enveloping methods such as SRE and BIOCLIM (Lazo, 2013). Similarly, in Nepal, several studies have been carried out regarding species habitat suitability using MaxEnt (Bai et al., 2018). The habitat suitability for mammals, birds, vegetation, and even invasive plant species has been previously conducted (Baidar et al., 2017, Thapa *et al*., 2018).

Owing to their population decline, the hunting of *C.sumatraensis*has been prohibited throughout Nepal (Wegge and Oli, 1997). Considering its threatened status, very little is known about the habitat, vegetation preference, and threats of *C.sumatraensis*in the Annapurna Conservation Area. The main objective of the study was to predictthe *C.sumatraensis*distribution pattern and to identify the existing threats in Annapurna Conservation Area (ACA) along with the habitat use and to develop a habitat suitability model for the *C.sumatraensis*in ACA using the MaxEnt model.

MATERIAL AND METHODS

Study area

The research was carried out in the Annapurna Conservation Area of Nepal during June and July 2020, which is located in the Annapurna ranges of the Central Himalayas in the Western Region of Nepal (Figure 1). Annapurna Conservation Area (ACA) is the largest protected area in Nepal with high biodiversity and is a treasure house for 1, 226 species of flowering plants, 105 mammals, 518 birds, 40 reptiles, and 23 amphibians (Inskipp, 2003). It has been a refuge for many endangered species, including the snow leopard, since its establishment. Hence, this study adds a new dimension to the conservation and management of the conservation area. ACA was established in 1986 and extended in 1992 and now covers an area of 762900 hectares. The extreme variation in topography and climate has resulted in an exceptionally high diversity of flora and fauna representing subtropical to alpine vegetation types.

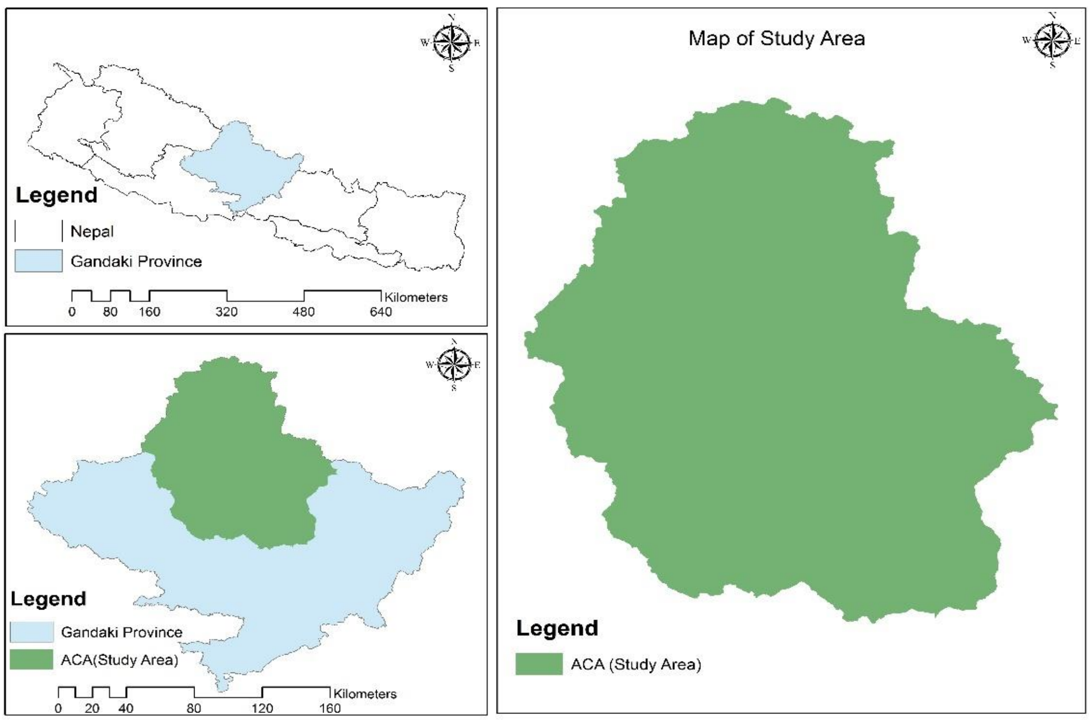

FIGURE 1. Map of the study area.

Sampling design

Important variables were measured in the field in order to estimate Importance Value Index (IVI), and these variables included trees, shrubs, and herbs. Similarly, *C. sumatraensis* sign and a type of disturbance were also observed in the plot. In addition to the record of the presence point in the plot, it was also recorded from outside the plots during a walk from one plot to another. For analysis of food availability, vegetation was estimated by conducting a field survey. Each sample plot had tree concentric circles of different radii for measurement of forest resources as 5.64 m radius for trees (area: 100 m^2), 1.78 m radius for shrubs (area: 10 m^2) and 0.56 m radius for herbs (1 m^2) was established (Figure 2). Similarly, vegetation was recorded in the appropriate plots and classified as trees with a diameter greater than 5 cm above DBH, shrubs with a height greater than 1 m, and herbs with a height less than 1 m.

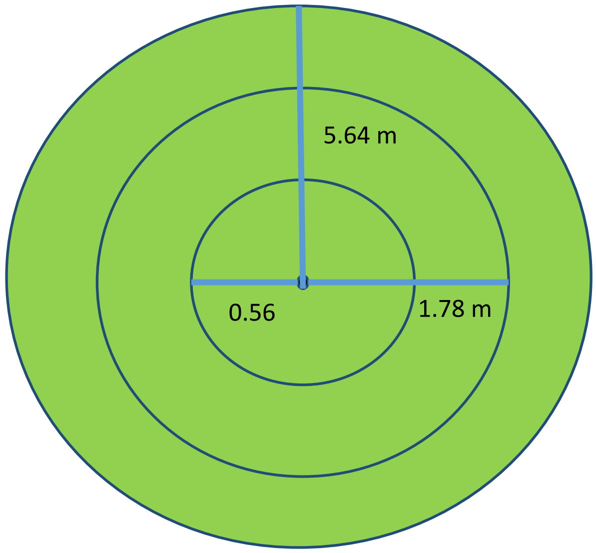

FIGURE 2. Sample plot design.

Data used

In this study, a variety of variables were used, including topographical variables (Digital Elevation Model (DEM), slope, and aspect), bioclimatic variables (worldclim), land use land cover (LULC), water bodies, roads, and riverbeds. These physical variables were taken from different sources: land use land cover (LULC) data was obtained from the International Centre for Integrated Mountain Development (ICIMOD), aspect and slope were taken from Shuttle Radar Topography Mission (SRTM) of the United States Geological Survey (USGS) site (earthexplorer.usgs.gov/), and the drainage and road data were obtained from DIVA-GIS (diva-gis.org). Table 1 gives a brief description of the input variables used for MaxEnt suitability prediction.

TABLE 1. List of input variables before processing.

Layer name	Spatial resolution	Pixel depth	Spatial data type	Projection system	Source
Presence data			Xlsx	UTM 44N	Field visit/NRC 2015
District boundary			polygon/line	WGS 84	ICIMOD
PAs boundary			polygon/line	WGS 85	ICIMOD
Settlement	30	16 bit signed	Point	WGS 86	ICIMOD
Southern part of the Sikles and Parche			polygon/line	WGS 87	PCTMCB
LULC	30	16 bit signed	Polygon	WGS 88	PCTMCB
Water bodies	30	16 bit signed	Polygon	WGS 89	Land use
River Beds	30	16 bit signed	Polygon	WGS 90	Land use
DEM	30	16 bit signed	Grid	WGS 91	ASTER
Slope	30	8 bit signed	Grid	WGS 92	DEM
Aspect	30	16 bit signed	Grid	WGS 93	DEM
Climate	1k	16 bit signed	Grid	WGS 94	Worldclim

Presence data

During a field trip around the study area, 16 presence records were collected. In addition to field data, some previous research and an ACP official's record were also incorporated for the purpose of running the MaxEnt model. For environmental information, the datasets for these 19 bioclimatic variables were derived from globally interpolated datasets for current conditions with a resolution of 1 km (source: http://www.worldclim.org) (Sharma et al., 2022). These variables were used for the modelling study because they are presumed to be the most relevant to animal existence, representing annual trends, seasonality, and extreme or limiting environmental factors (Sodhi et al., 2008). Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variablesfor characterizing a species range (Buermann et al., 2008). Several studies have highlighted strong relationships between species abundance and bioclimatic variables (current version 2.0) (Phillips et al., 2006; Jeschke and Strayer, 2008). This scheme follows that of ANUCLIM, except that for temperature seasonality the standard deviation was used because a coefficient of variation does not make sense with temperatures between -1 and 1 (worldclim.org). The various bioclimatic variables, along with other physical variables, are mentioned in Table 2.

TABLE 2. Bioclimatic variables.

Sr.	BIO	Name	Resolutions
1	BIO1	Annual Mean Temperature	1km
2	BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp)	1km
3	BIO3	Isothermality (BIO2/BIO7) (* 100)	1km
4	BIO4	Temperature Seasonality (standard deviation *100)	1km
5	BIO5	Max Temperature of Warmest Month	1km
6	BIO6	Min Temperature of Coldest Month	1km
7	BIO7	Temperature Annual Range (BIO5-BIO6)	1km
8	BIO8	Mean Temperature of Wettest Quarter	1km
9	BIO9	Mean Temperature of Driest Quarter	1km
10	BIO10	Mean Temperature of Warmest Quarter	1km
11	BIO11	Mean Temperature of Coldest Quarter	1km
12	BIO12	Annual Precipitation	1km
13	BIO13	Precipitation of Wettest Month	1km
14	BIO14	Precipitation of Driest Month	1km
15	BIO15	Precipitation Seasonality (Coefficient of Variation)	1km
16	BIO16	Precipitation of Wettest Quarter	1km
17	BIO17	Precipitation of Driest Quarter	1km
18	BIO18	Precipitation of Warmest Quarter	1km
19	BIO19	Precipitation of Coldest Quarter	1km

Topographical variable

A DEM shows an array of elevations of the land surface at each spatial location (I, j). Terrain visualization using satellite images in association with DEMs has long been explored as a promising tool in environmental studies (Gugan, 1988). This data layer was downloaded from earthexplorer.usgs.gov/, which was used for the generation of elevation, slope, and aspect.

Slope represents the rate of change of elevation for each DEM cell. It's the first derivative of DEM. The slope was calculated from the ASTERGMT data using ArcGIS desktop's "Spatial Analysis" tool. For the purpose of habitat suitability analysis, the generated slope was reclassified into 9 classes (Figure 3).

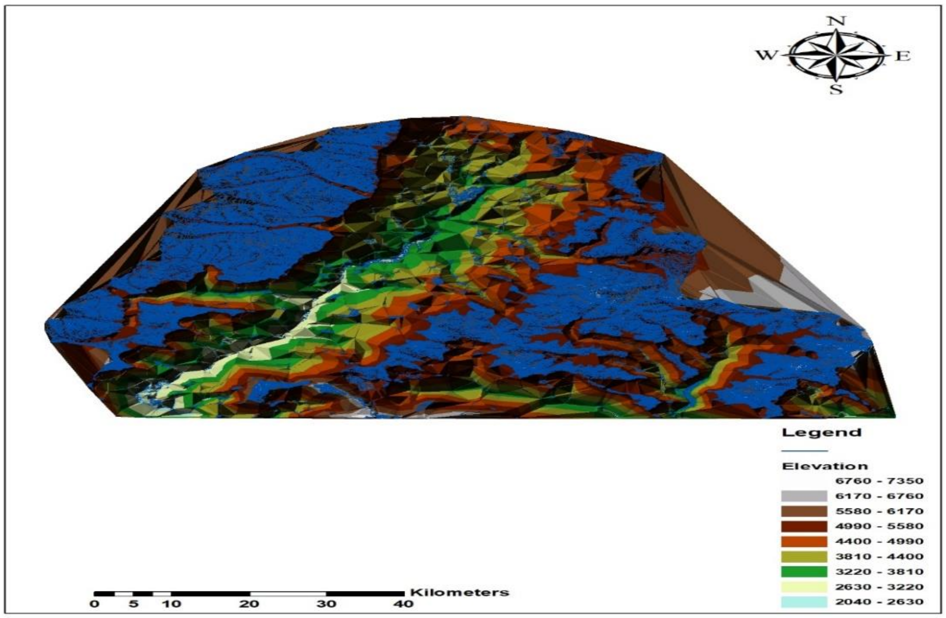

FIGURE 3. Slope map of Landscape.

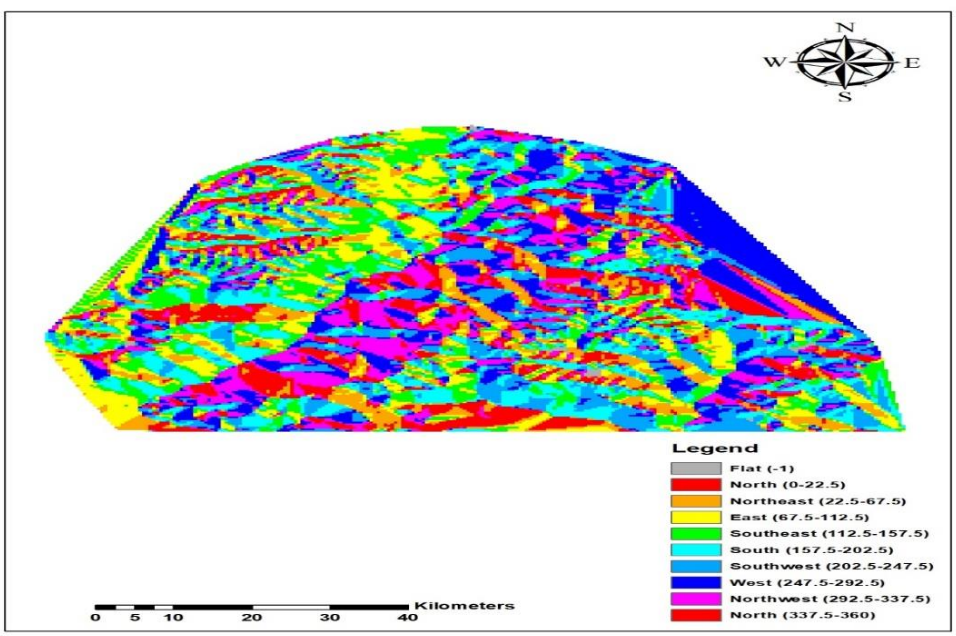

FIGURE 4. Aspect map of the landscape.

Data collection

An aspect is the direction towards which a slope is facing. It was derived using the "Spatial Analysis" tool of ArcGIS Desktop and further reclassified into 9 classes (Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest) (Figure 4).

The survey was done by purposive sampling with ACP officials, Divisional Forest office staff, local people who have many ideas about *C. sumatraensis*, and other knowledgeable people to obtain information regarding threats. Group discussions were carried out by pursuing the Participatory Method given by Martin (1995), according to which theoretical issues and practical considerations in the conduct and analysis of focus groups were presented and discussed. A focused group discussion segregated by gender was organized to get a better understanding of the availability of the target species and threats to it. The focus group discussion was carried out with women and other people who frequently visited the *C. Sumatraensis* prone areas. A focus group discussion (2 meetings), a questionnaire survey of households with 50 respondents, and a total of three key informant interviews were performed to gather information about the attitude and perception of local people towards *C. sumatraensis*.

Data analysis

Important Value Index (IVI) Calculation

From the data gathered from the field, the IVI for each species was calculated. According to Zobel et al. (1987), the following method was performed for IVI calculation:

i. **Density and Relative density (RD)**

Density of species A= $\frac{Total\ number\ of\ individuals\ of\ species\ A}{\text{Total number of plots sampled} * \text{area of a plot}}$

Relative density of species A= $\frac{Total\ individuals\ of\ species\ A}{\text{Total individuals of all species}}$

ii. **Frequency and Relative frequency (RF)**

Frequency of species A= $\frac{\text{No of plots in which species A occurs}}{Total\ number\ of\ plot\ sampled}$ *100

Relative Frequency of species A= $\frac{\text{Frequency value of species A}}{\text{Total frequency value of all species}}$ *100

iii. **Relative dominance (R Dom.)**

Relative dominance of species A= $\frac{\text{Total basal area of species A}}{\text{Total basal area of all species}}$ *100

iv. **Basal area**

The basal area of a species is the sum total of the basal areas of all trees of a species, which was calculated using the following relation:

Basal area= $\pi(\frac{d}{2})^2$, where, d=diameter at breast height.

v. Relative cover (R Cov)

$$\text{Relative cover of species A} = \frac{Average\ cover\ of\ species\ A}{Sum\ of\ Average\ cover\ of\ all\ species} \times 100$$

vi. Importance value index (IVI)

IVI was obtained by the summation of relative density, relative frequency, and relative dominance.

$IVI\ of\ Tree\ \&\ Shrub = Relative\ density + Relative\ frequency + Relative\ dominance$

Similarly, IVI of Herb $= Relative\ density + Relative\ frequency + Relative\ cover$

Suitability analysis

Software and Tools

The various software and tools, such as ArcGIS 10.2.1, Microsoft Office Suite 2012, Google Earth Pro, and MaxEnt 3.4.1 (prediction mapping), were used for the processing of the data depending on its nature (Table 3 & 4). Input variables were processed with relevant software to make them readable by MaxEnt Model. Presence data was converted to CSV (Comma-separated Value) using MS Excel 2012. Presence data collected in WGS UTM format was plotted and transformed to WGS 1984 (DD) using ArcGIS data management tools. After the transformation, the attributes were exported to MS Excel 2012 and converted to CSV (Comma-separated value) format. All the grid format and shape file format variables were exported to ArcGIS and processed using the ArcGIS 10.2.1 model builder. A data management tool was used for the processing of grid format. Vector (shape file) data was processed using data management and conversion tools in the ArcGIS model builder.

TABLE 3. List of tools for vector data preparation.

Tools	Description
Add layer	Source layer (world bioclimatic)
Project	UTM
Resample	30 m resolution No data = 0
Copy	Pixel depth = 16 bit unregistered
Project	WGS 1984 (degree decimal)
Extract	By smallest layer
Raster to ASCII	Readable by MaxEnt

MaxEnt

All the processed variables are then imported to the MaxEnt model for the prediction of the probability of distribution of *C. Sumatraensis* both at the landscape level and localized level. At landscape level distribution prediction, there is no exact record in Nepal, whereas at localized level distribution prediction, 16 sign records collected during a field visit were used. A sample requires a presence point (CSV format) directly, while environmental layers take environmental variables (ASCII format). Create response curves, make pictures of predictions, and the Jackknife test was used to check and measure the importance of variables. Finally, the output format was chosen for logistics. Additional configuration was used during prediction and a total of 15 random partitions of the occurrence localities were made in order to assess the average behaviour of the algorithms (via Wilcoxon signed-rank tests). Each partition was created by randomly selecting 70% of the occurrence localities as training data, with the remaining 30% reserved for testing the resulting models. There is a risk of over-prediction or under-prediction of the relationship by the model if the model doesn't have enough time to converge. To avoid this, the maximum number of iterations is increased to 5000 (where it is 500 by default). The algorithms were run

TABLE 4. List of input variables after processing**.**

Layer Name	Spatial resolution (M)	Pixel Depth (radiometric Resolution)	Spatial data type	Projection System	Variable
Presence Data			CSV	WGS 84	
District boundary			Polygon/ Line	WGS 84	
Southern side of Chure hill			Polygon/ Line	WGS 84	
Settlement	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical
Land use	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical
Water bodies	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical
River Beds	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical
DEM	30	16 bit unsigned	GeoTIFF	WGS 84	Continuous
Slope	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical
Aspect	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical
Water bodies	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical
Climate	30	16 bit unsigned	GeoTIFF	WGS 84	Categorical

with two sets of habitat sites; first at the landscape level, in which presence points (direct sightings) were extracted from previous data (if available), and second at the localized level, in which presence points (direct sightings and signs) were collected during a field visit by the researcher himself.

Analysis of disruptions and existing threats

The various types of disturbances were recorded from the sample plot inventory. The occurrence of disturbance data was then imported to SPSS version 22 and used descriptive statistics in order to calculate the frequency and percentage of the occurrence. A ranking system based on the Relative Threat Factor Severity Index (RTSFI) by Kiringe and Okello (2007) was used for the assessment of threats. A tally of the threat factors to the *C. Sumatraensis* was computed and calculated as indicators of serious threat factors. The following simple formula was used to prioritize the threats to define the (RTFSI).

$$Mean\ score\ of\ each\ threat\ factor = \frac{\text{Sum of all the scores for that particular threat factor}}{\text{The total number of respondents}}$$

$$RTFSI = \frac{\text{The mean score for a particular threat factor}}{\text{The maximum possible score}}$$

The RTFSI was used to categorize threat severity, with severe threats having the highest RTFSI and least threats having the lowest.

RESULTS

Food availability

Vegetation analysis

Identification of habitat preferences of *C. Sumatraensis* was done by using IVI of different species of trees found in the study area. The resulting graph shows the preference of the wildlife in habitats containing different tree species; with *Quercus semecarpifolia* (76.22) and *Rhododendron arboreum* (62.31) preferred the most, respectively (Figure 5).

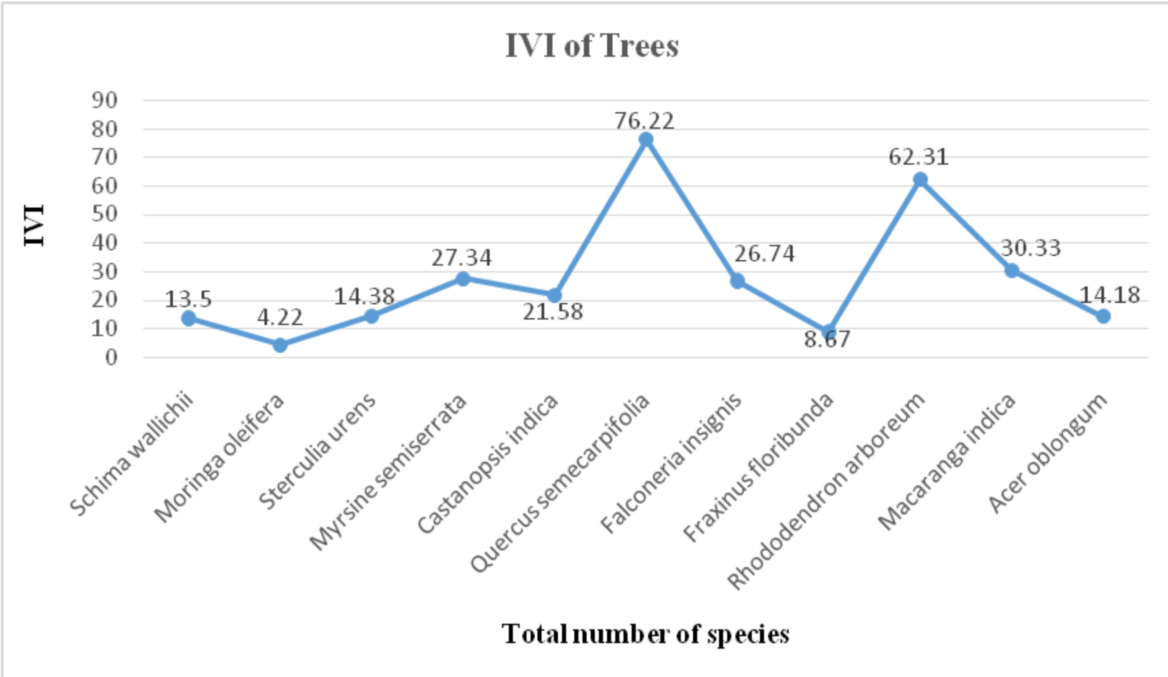

FIGURE 5. IVI of tree species.

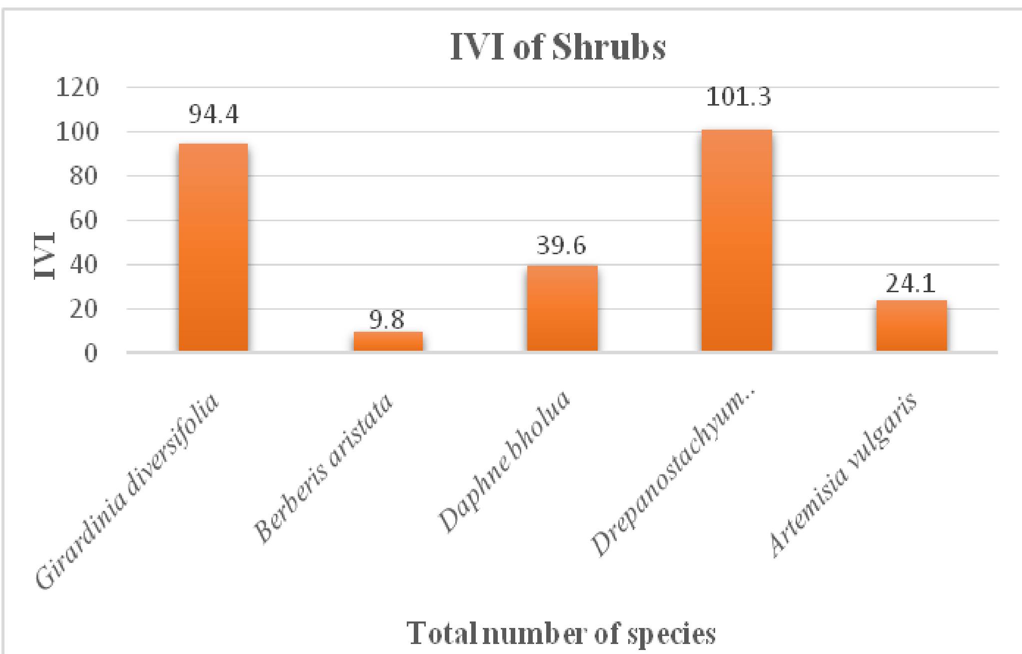

FIGURE 6. IVI of Shrubs.

Identification of habitat preferences of *C. Sumatraensis* was done by using IVI of different species of shrubs found in the study area. The resulting graph shows the preference of the wildlife in habitats containing different shrub species; with *Drepanostachyum falcatum* (101.3) and *Girardinia diversifolia* (94.4) preferred the most, respectively (Figure 6).

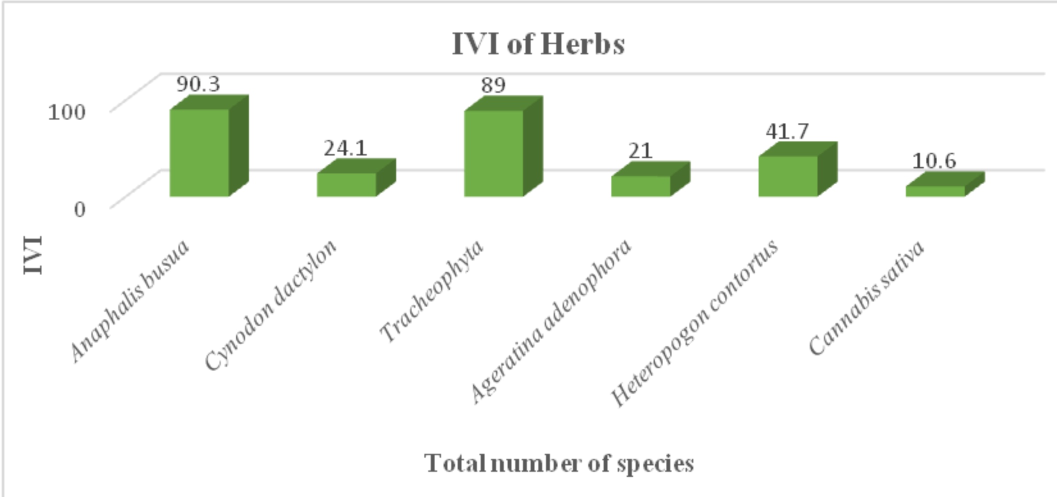

Figure 7. IVI of Herbs**.**

Similarly, using IVI of different species of herbs found in the study area. The resulting graph shows the preference of the wildlife in habitats containing different herb species, with *Anaphalis busua* (90.3) and *Tracheophyta* (89) preferred the most, respectively (Figure 7).

Habitat suitability and associated factors

Figure 8 shows the probability of occurrence of *C. sumatraensis* generated by the MaxEnt Model. Out of the total area (762900 ha.) of the Annapurna Conservation Area, nearly 76000 ha. of area was found to be suitable, whereas the rest of the area was found to be less suitable. The calculated habitat suitability for *C. sumatraensis* determined that 18.3% of the total area was highly suitable (represented by red colour), 16.8% was moderately suitable (represented by light blue colour) and the remaining 64.76% was less suitable habitat (represented by dark blue colour).

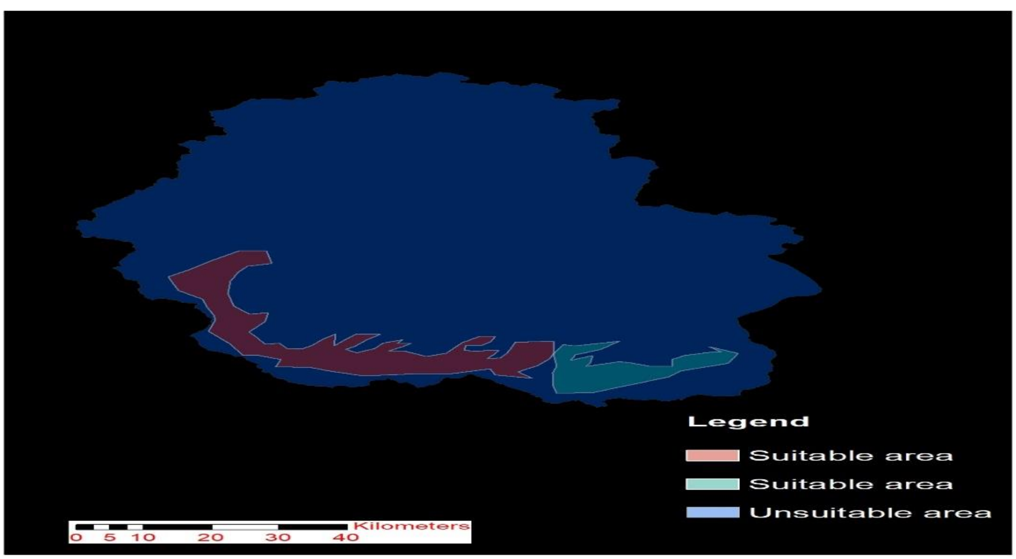

Figure 8. MaxEnt Suitability Map at Landscape level.

Analysis of omission

The test of omission rate and prediction area as a function of the cumulative threshold, averaged over the replicate runs. The omission rate should be close to the predicted omission rate because of the definition of the cumulative threshold.

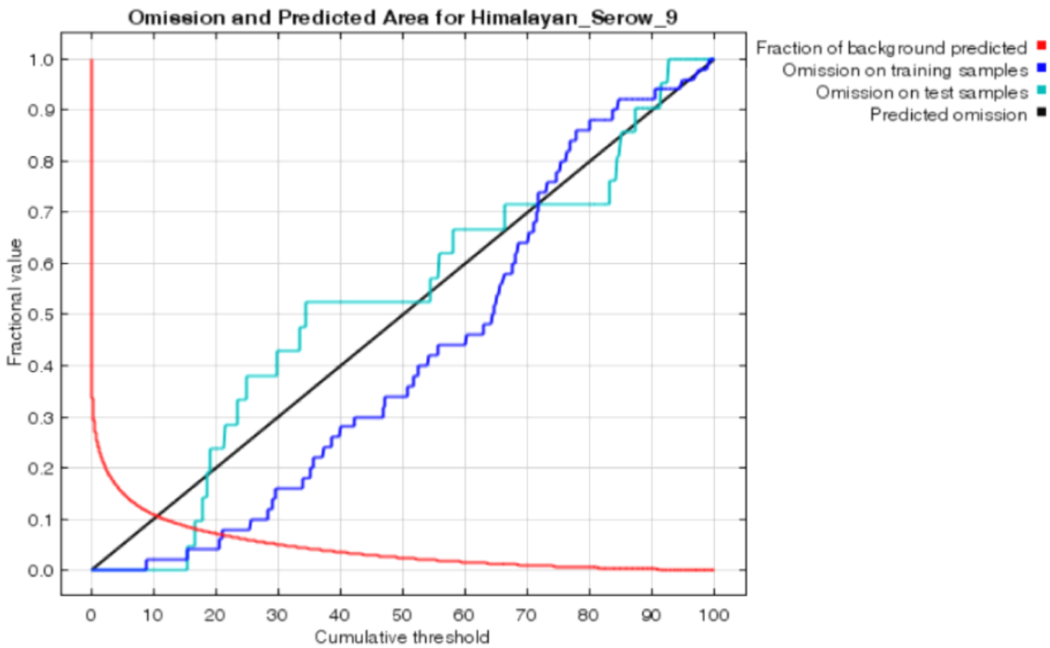

FIGURE 9. Analysis of Omission**.**

3.2.2. ROC/AUC

Figure 10 shows the receiver operating characteristic (ROC) curve for the same data, again averaged over the replicate runs. Note that the specificity is defined using the predicted area rather than the true commission. The average test AUC for the replicate runs is 0.975 and the standard deviation is 0.003(Figure 10), which indicated that the model performed well with high accuracy (Swets, 1988).

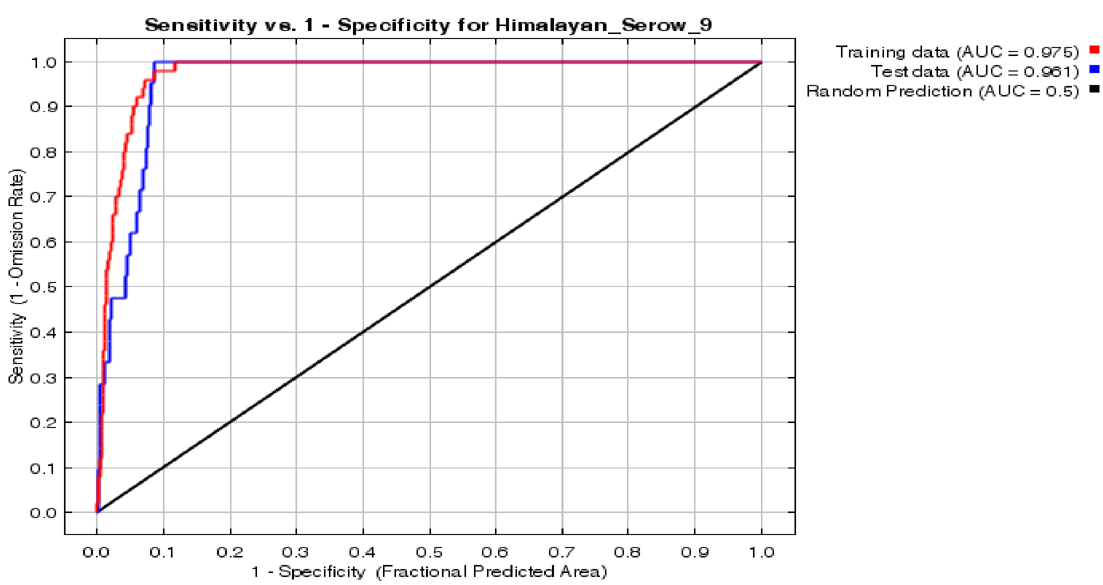

FIGURE 10. AUC curve suitability modeling.

Suitability map

Analysis of variable contributions

The following table gives estimates of the relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change in the absolute value of lambda is negative. For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is re-evaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. As with the variable Jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated. The values displayed are averages of replicated runs.

TABLE 5. Percent contribution of variables to Model at landscape level.

S. N	Variable	Percent contribution	Permutation importance
1	Lulc	36	27.2
2	wb_cl	13.7	0
3	bio_6	12.5	0
4	bio_14	5.1	2.3
5	bio_8	4.3	1.6
6	bio_18	3.8	3.7
7	slop_cl	3.6	0.2
8	bio_5	2.9	3.3
9	bio_13	2.6	6.9
10	bio_3	2.2	0.2
11	Elevate	2	30.9
12	bio_17	1.7	3.4
13	rbed_cl	1.6	0.2
14	bio_4	1.6	1.4
15	bio_15	1.5	2.7
16	bio_16	1.4	0.2
17	bio_7	0.7	0.3
18	bio_9	0.5	0
19	bio_12	0.5	2.7
20	bio_2	0.4	10.2
21	bio_10	0.4	0
22	bio_11	0.3	0.1
23	bio_1	0.2	0.1
24	sett_cl	0.2	0.3
25	asp_cl	0.1	0
26	bio_19	0.1	2

The following picture shows the results of the Jackknife test of variable importance. The environmental variable with the highest gain when used in isolation is elevation, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is LULC, which therefore appears to have the most information that isn't present in the other variables. The values displayed are averages of replicated runs.

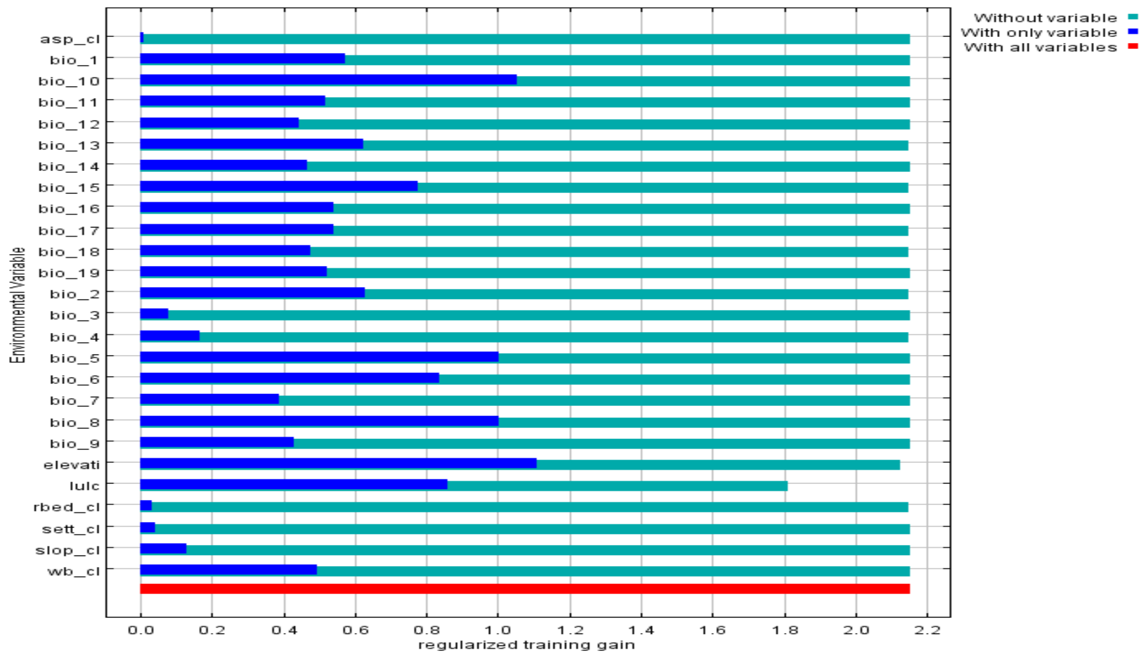

FIGURE 11. Jackknife test of importance of variable in model.

Attitude and Perception of local people

Local people strongly believed that the population of *C. sumatraensis*had been declining day by day. The majority of people (90%) expressed positive attitudes toward *C. sumatraensis*. About 65% of local people said that the population of *C. sumatraensis*has been declining at a high rate. According to herders and other local people, the main cause of the population's declining is poaching; every year a large number of snares are collected from the study site. Many respondents blamed poaching, killing by predators, and human and livestock disturbance in its habitat as the main causes of population decline. Villagers agreed that poaching activities have been reduced in recent years as compared to the past year.

Threats to existing habitats

In the study area, poaching and hunting (0.927), open grazing (0.727), illegal resource collection (0.617), climate change (0.573) and development activities (0.447) were observed as major threats to the *C. sumatraensis* (Figure 12). *C. sumatraensis* poaching is one of the main threats in the study area. Generally, poachers prefer not to hunt *C. sumatraensis*—they only use this species if they cannot find other species. It is said that *C. sumatraensis* meat is not as tasty compared with other ungulates. As a result, hunting is limited and secretive. We found many snares in our study area, especially in the bamboo and deurali-rich sites where there is a high population of *C. sumatraensis*. The development of agriculture areas, the high dependence of local people in *C. sumatraensis* habitat for fuel wood and timber, increasing hotels, trekking routes, increasing settlement areas, and increasing distance from forest has played a critical role in habitat fragmentation, which has brought a critical change in the wildlife profile of the study area in the long run. This habitat fragmentation has a negative impact on the continued survival of the *C. sumatraensis* and other different wildlife species in the area.

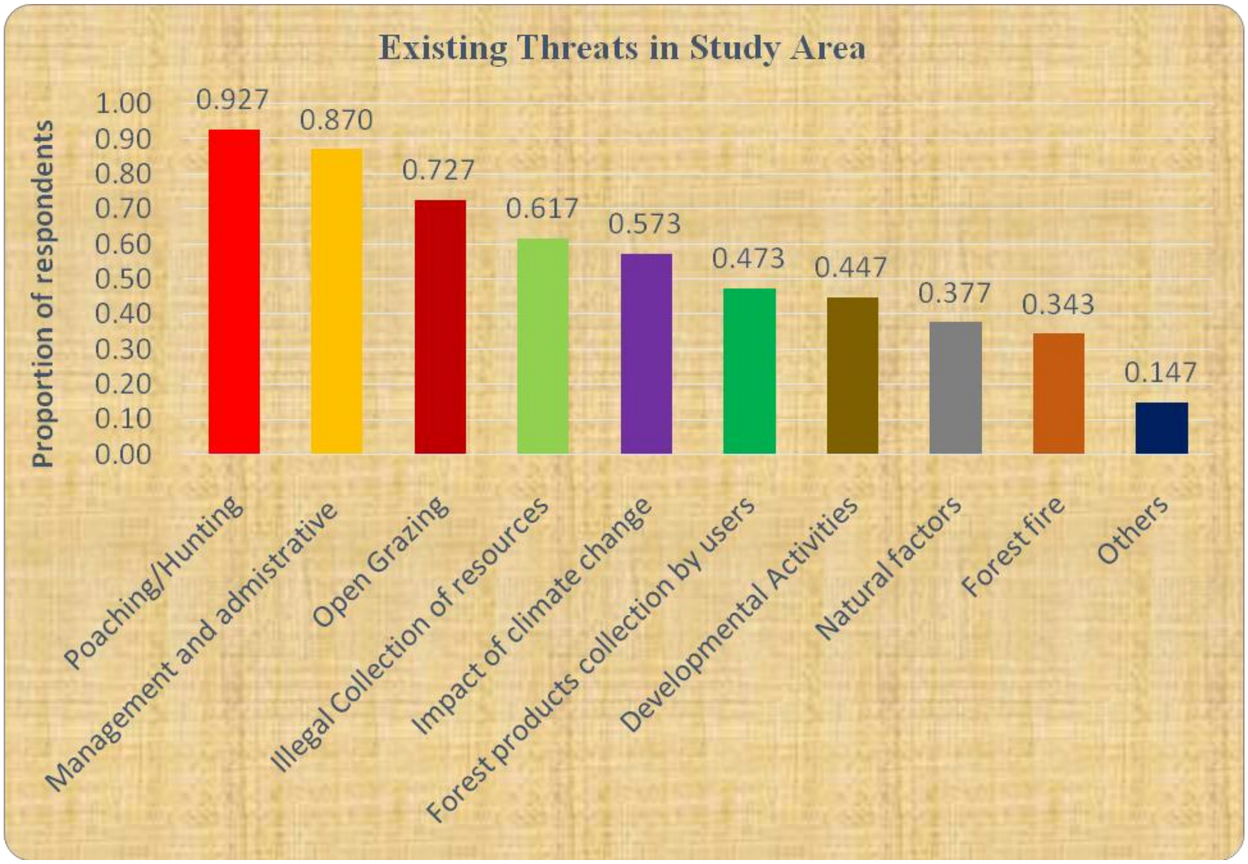

FIGURE 12. Existing threats to serow in Study area.

The loss of a large population of the *C. sumatraensis* and other ungulates from the study area has created consequent changes in the abundance of predator species like clouded leopards, common leopards, brown bears, and black bears. Generally, such predators attack the local livestock only when their natural prey is either depleted or hard to find, so it is one indicator of the decline of the population of *C. sumatraensis* and other ungulates from the study area. Owing to high seasonality and low primary productivity, the Himalayan region supports a relatively low ungulate and herbivore biomass (Aryal, 2005). It is therefore obvious that with the increase in the biomass of domestic livestock in many areas, wild ungulates such as *C. sumatraensis* have suffered competitive exclusion.

DISCUSSION

Aryal (2009) reported only 10% of the area as suitable habitat in ACA, which is lower than the present study. It shows that there is improvement in habitat conditions in the ACA region with the implementation of conservation activities. A *Quercus semecarpifolia* and *Rhododendron arboreum* dominated forest was found as the preferred habitat, which was consistent with the previous findings (Aryal, 2009; Giri et al., 2011). Similarly, in preferred habitat, *Drepanostachyum falcatum* and *Girardinia diversifolia* were the dominant shrubs and *Anaphalis busua* and *Tracheophyta* were dominant herbs, which is similar to the results reported by Aryal (2009) and Giri et al. (2011). Poaching and hunting, open grazing, and illegal collection of resources were the major threats to *C. sumatraensis* conservation in ACA. For the threat assessment, the Relative Threat Factor Severity Index was used to rank the threats. Poaching and hunting (0.927), open grazing (0.727), illegal resource collection (0.617), climate change (0.573) and development activities (0.447) were observed as major threats to the *C. sumatraensis*, which is similar to the threats identified by official documents, viz. the ACAP management plan and the

National Biodiversity Strategy and Action Plan for biodiversity conservation (GoN, 2015). In this study, a major drawback of the MaxEnt is identified: the model cannot distinguish the nature of the presence point, which supports the work of Phillips and his coworkers (2009). Direct competition with humans is thus clearly a cause for concern in the conservation of species. Additionally, the resulting development of human settlements, human trails, and agricultural lands has led to the fragmentation of *C. sumatraensis* habitat. For example, the main corridor connecting the *C. sumatraensis* populations of Landruk and Ghandruk (Tadapani forest) has been fragmented by settlement and agricultural land. As a consequence, these populations are now isolated. This has had negative impacts on *C. sumatraensis* and other wildlife species in the area (Aryal, 2009). *C. sumatraensis* are a shy species, preferring to live away from human disturbance, but in the study area, human settlement had encroached as close as 400m to the habitat of these animals. The pressures due to direct competition for resources with humans and habitat fragmentation are important concerns for the conservation of *C. sumatraensis* in ACA.

CONCLUSION

The research concluded that *C. sumatraensis* preferred forests dominated by *Quercus semecarpifolia* and *Rhododendron arboreum*. Similarly, in the preferred habitat, *Drepanostachyum falcatum* and *Girardinia diversifolia* were the dominant shrubs, and *Anaphalis busua* and *Tracheophyta* were dominant herbs by IVI analysis. RTFSC analysis showed that poaching and hunting, management, and administrative divisions of the area were major threats to its habitat. These species have more available funds for their conservation and management through national and international sources compared to other species. This situation results in a lack of knowledge about the illegal market value of species such as serow, hispid hare, etc. Therefore, concerned agencies and researchers should just give equal emphasis to in situ conservation of low illegal market value species such as *C. sumatraensis*, which is a favorite prey species of threatened species like leopards. The major problems in *C. sumatraensis* habitats are habitat fragmentation, land use changes, reduction of the *C. sumatraensis*population, conflicts between *C. sumatraensis* and predators and villagers, livestock grazing in *C. sumatraensis* habitats, and poaching. Further research and conservation education are essential to conserve this species. It is not only *Arundinaria* spp. for which *C. sumatraensis* compete with villagers in ACA. The tree species used as food and cover by *C. sumatraensis* are *Rhododendron* spp., *Lyonia* spp., *Acer* spp., etc. They are also important firewood and timber production species in the area and are harvested at high rates for infrastructure development. Further, some of the herbs and shrubs that have been identified in the diet of *C. sumatraensis* are collected for their medicinal value and for other domestic use values. Direct competition with humans is thus clearly a cause for concern in the conservation of *C. sumatraensis*. Human settlements and associated use of land for agriculture are fragmenting *C. sumatraensis* habitat, in some cases, causing populations to become isolated. The pressures due to direct competition for resources with humans and habitat fragmentation are important concerns for the conservation of *C. sumatraensis* in ACA. This study strongly recommended the necessity of effective law enforcement in coordination with local people to reduce the threat of hunting and poaching. Conservation of preferred species is equally important for the enhancement of *C. sumatraensis*. Further research and conservation education are important for the conservation of this species.

LITERATURE CITED

Aronoff, S. (1989). Geographic information systems: a management perspective.

Aryal, A. (2005). "Status and distribution of Musk Deer ‘*Moschus chrysogaster*’ in Annapurna Conservation Area of Manang district" a report submitted to ITNC, UK.

Aryal, A. (2008). Status and Conservation of Himalayan Serow (Capricornis sumatraensis. thar) in Annapurna Conservation Area of Nepal. *BRTF Nepal*.

Aryal, A. (2009). Conservation status and population density of Himalayan serow (Capricornis sumatraensis) in Annapurna Conservation Area of Nepal. *The Initiation*, *3*, 12-19. DOI: https://doi.org/10.3126/init.v3i0.2423

Bai, D.F., Chen, P.J., Atzeni, L., Cering, L., Li, Q. and Shi, K. (2018). Assessment of habitat suitability of the snow leopard (*Panthera uncia*) in Qomolangma National Nature Reserve based on MaxEnt modelling. *Zoological Research*, 39(6): 373. DOI: 10.24272/j.issn.2095-8137.2018.057

Baidar, T., Shrestha, A.B., Ranjit, R., Adhikari, R., Ghimire, S. and Shrestha, N. (2017). Impact assessment of *Mikania micrantha* on land cover and MaxEnt modelling to predict its potential invasion sites. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42: 305.

Bhattacharya, T., Bashir, T., Poudyal, K., Sathyakumar, S. and Saha, G. K. (2012). Distribution, occupancy and activity patterns of goral (Nemorhaedus goral) and serow (C*apricornis* thar) in Khangchendzonga Biosphere Reserve, Sikkim, India. Mammal study, 37(3), 173-181. DOI: https://doi.org/10.3106/041.037.0302

Buermann, W., Saatchi, S., Smith, T. B., Zutta, B. R., Chaves, J. A., Milá, B. and Graham, C. H. (2008). Predicting species distributions across the Amazonian and Andean regions using remote sensing data. *Journal of Biogeography*, *35*(7), 1160-1176.

Chaudhary, R.P. (1998). Biodiversity in Nepal – Status and Conservation. Tecpress Books, Thailand, Bangkok.

Elith, J. and Leathwick, J. R. (2009). Species distribution models: ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution and Systematics,* 40(1), 677-697. DOI: https://doi.org/10.1146/annurev.ecolsys.110308.120159

GoN, (2015). Nature Conservation National Strategic Framework for Sustainable Development (2015-2030). National Planning Commission. Singha Durbar, Kathmandu.

Gugan, D. J. and Dowman, I. J. (1988). Accuracy and completeness of topographic mapping from SPOT imagery. *The Photogrammetric Record*, *12*(72), 787-796.

Horning, N., Robinson, J. A., Sterling, E. J., Spector, S. and Turner, W. (2010). *Remote sensing for ecology and conservation: a handbook of techniques*. Oxford University Press.

Inskipp, C. and Inskipp T. (2003). Bird conservation priorities of the Annapurna Conservation Area. Report submitted to UNEP-WCMC/King Mahendra Trust for Nature Conservation/Annapurna Conservation Area Project; 2003.

Jeschke, J. M. and Strayer, D. L. (2008). Usefulness of bioclimatic models for studying climate change and invasive species. Annals of the New york Academy of Sciences, 1134(1): 1-24. DOI: https://doi.org/10.1196/annals.1439.002

Jnawali, S. R., Baral, H., Lee, S., Acharya, K., Upadhyay, G., Pandey, M. and Griffiths, J. (2011). The status of Nepal mammals: the national red list series, department of national Parks and wildlife

conservation Kathmandu, Nepal. *Preface by Simon M. Stuart Chair IUCN Species Survival Commission The Status of Nepal's Mammals: The National Red List Series*, *4*.

Kiringe, J. and Okello, M. (2007): Threats and their relative severity to wildlife protected areas of Kenya. *Applied Ecology and Environmental Research*, 5(2):49-62.

Lazo, J.D., van Gils, H., Groen, T. and Navarro-Cerrillo, R. (2013). *Transferability of species distribution models: A case study of the fungus Phytophthora cinnamomi in andalusia and Southwest Australia*. University of Twente Faculty of Geo-Information and Earth Observation (ITC).

Mishra, H. R. andMierow, D. (1976). *Wild animals of Nepal*. Ratna Pustak Bhandar.

Mori, E., Nerva, L. and Lovari, S. (2019). Reclassification of the serows and gorals: the end of a neverending story?. *Mammal Review*, *49*(3), 256-262. DOI: https://doi.org/10.1111/mam.12154

Phan, T. D., Nijhawan, S., Li, S. and Xiao, L. (2020). *Capricornis sumatraensis*. The IUCN Red List of Threatened Species 2020: e. T162916735A162916910.

Phillips, S. J., Anderson, R. P. and Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. Ecological Modelling, 190(3-4): 231-259. DOI: https://doi.org/10.1016/j.ecolmodel.2005.03.026

Sillero, N. (2011). What does ecological modelling model? A proposed classification of ecological niche models based on their underlying methods. *Ecological Modelling*, *222*(8), 1343-1346. DOI: https://doi.org/10.1016/j.ecolmodel.2011.01.018

Sodhi, N. S., Bickford, D., Diesmos, A. C., Lee, T. M., Koh, L. P., Brook, B. W. and Bradshaw, C. J. (2008). Measuring the meltdown: drivers of global amphibian extinction and decline. *PloS one*, *3*(2), e1636.

Thapa, S., Chitale, V., Rijal, S.J., Bisht, N. and Shrestha, B.B. (2018). Understanding the dynamics in distribution of invasive alien plant species under predicted climate change in Western Himalaya. *PloS ONE*, 13(4): e0195752. DOI: https://doi.org/10.1371/journal.pone .0195752

Wegge, P. and Oli, M.K. (1997). Country report on Nepal. in Shackleton, D. M. (ed) & the IUCN/SSC Caprinae Specialist Group. Wild Sheep and Goats and their Relatives. Status and Conservation Action Plan for Caprinae. IUCN. Gland, Switzerland and Cambridge, UK. pp 231-239.

Zobel, D. B., Jha, P. K., Behan, M. J. and Yadav, U. K. R. (1987). A Practical Manual for Ecology. Ratna Pustak Distributor, Nepal.